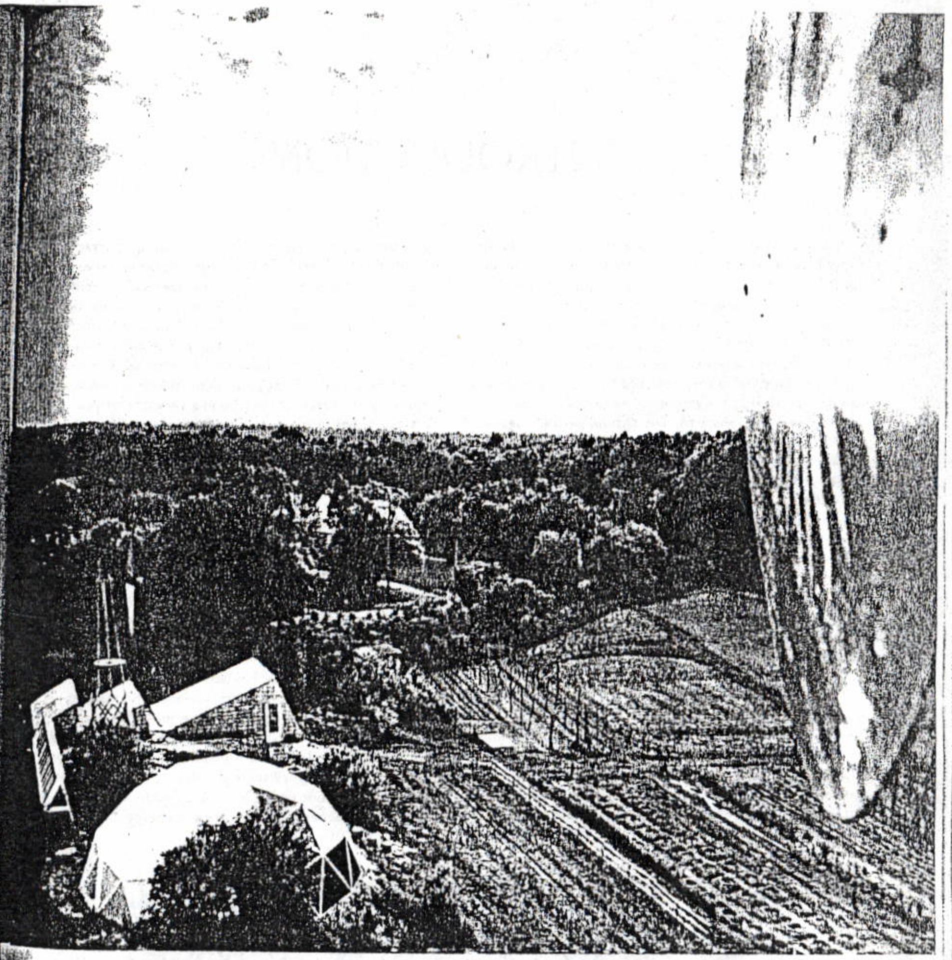


Agriculture and Energy

INTRODUCTION

For several generations we have lived in a society alienated from an involvement in its basic functions of support. Not until the flow of supplies, which we have come to think of as our right, is interrupted do we begin to question the sources upon which we depend. The gas crisis of 1973 seems to have been largely forgotten, with the demand for larger cars again on the rise, and although it was a contrived event, it should be seen for what it is—an indication that the resources we take so much for granted are not unlimited. The natural gas shortages of 1977 may well lead to a more serious examination of fuel sources. But as yet there seems to be little broad-based recognition of the fact that our agriculture, our industry, our transport, and much of our electricity are dependent on fossil fuels, and that although exactly how much we have and how long they will last are hotly debated, the amounts are finite. Sooner or later substitutes must be found. It is most facile for many of us to think in terms of a technological fix. "They'll think of something." But the technological fix is almost invariably at further expense to our already damaged environment. The most dramatic example of this is the ultimate technological horror, nuclear power.

Although we feel it to be our work as New Alchemists to devote ourselves to finding ecological alternatives to questions of basic life support systems, a New Alchemy publication would not be entirely honest without a statement of our unalterable opposition to nuclear power. It is compelling evidence of the manipulation of information when there is still so little public knowledge of the dangers to which it exposes not only ourselves and our children, but countless succeeding generations. Possibilities of accidents (and there have been several unnerving near-misses), sabotage, leakage, and the lethal threat posed by the use of plutonium, not to mention the problems of the storage of wastes, are not widely known. The immorality of a legacy that will contaminate the Earth for two-hundred-and-fifty-thousand years, which is the half-life of plutonium, conveys a strange, almost surreal lack of concern in a society that professes a belief in equality of opportunity in life and a love for its children. Perhaps the most succinct summary of the terrifyingly rational insanity is that nuclear nergy is predicated upon both technological and human infallibility.

Meanwhile the sun and wind appear to be with us for as close to eternity as need concern us. With these, human energy needs could adequately be met, given even modest encouragement in developing the necessary technology—which would be integrated in decentralized, smaller-scale energy patterns and used in combination with other sources such as biofuels, geothermal and tidal power.

The articles in this section describe much of what is wrong with present agricultural and energy practices. They are intended to be read as critiques, as indeed they are, but not to be interpreted as endpoints in our thinking. We have tried, at New Alchemy, to shift our intellectual paradigm until these problems no longer loom as insuperable, but rather become a touchstone for biological approaches to agriculture and energy.

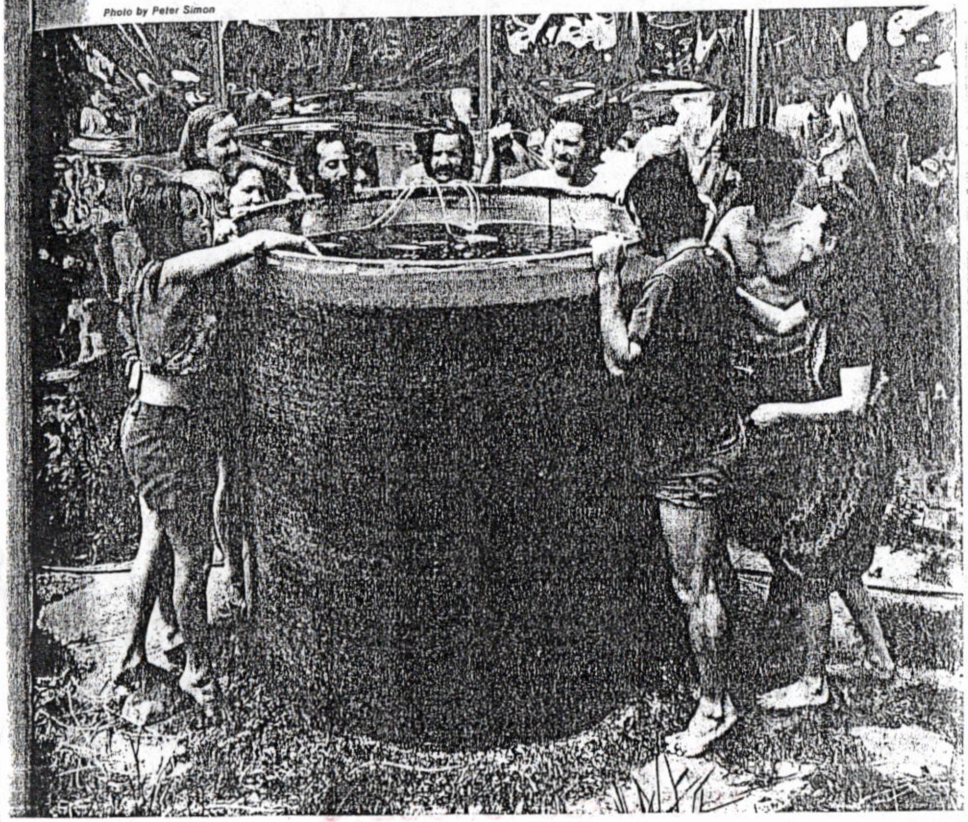
We find that there are resources, often in the strangest places, as we become less concerned with high energy and more concerned with diverse wholes. If we are willing to change the way we live, then we can begin to restore and reconstruct. By passing through the portals of nature, we can begin to work with or through her so that the scars begin to heal. The path will involve the three strands of practicality, science on a small and human scale, and a wisdom that is philosophical, even mystical. Separately change cannot come about, but perhaps...... and this is only perhaps, together the world will begin to sing.

It is easy to begin. The Ark and the Backyard Fish Farms reflect wholistic and small-scale thinking, and although they are early explorations into man in nature, they will help give confidence and directions.

Time is not on our side. Hence the urgency and tone of the "Journal." To some, like Odum, our survival is at stake; should they be proved wrong, we still stand to gain. If they are right, there can be virtually no alternative that is not hell, until the living order of the earth's mantle is restored.

– John Todd

Photo by Peter Simon



at this time, the composting process is expensive and there is little demand for the benefits of compost; operating costs range from about $5.00-$15.00 per ton, or about the same price as incineration.[68] Also the bulk of organic wastes makes them impractical to the farmer when compared to salt fertilizers that can be applied easily by machines or in irrigation water.

On the other hand, the shipment of millions of tons of agricultural produce from the country to the city and then into waterways or up into the air is a fundamental example of how rural and urban problems have been separated from their common ecology. The recycling of organic wastes on farmlands has the potential of creating new jobs, reversing the rapid loss of humus in farm soils and offering a low-energy alternative to agriculture (Table X). Most important, it provides the first positive step towards the much-needed integration of cities and farms and the mutual solution of urban and rural problems.

Organic matter is not only a valuable fertilizer and soil conditioner, it can also be converted into energy sources. For example, the U. S. produces about 136 million tons of easily available organic solids each year (Table VIII). This is equivalent to: 170 million barrels of oil (3% of 1971 U. S. consumption) or 1.36 trillion cubic feet of methane gas (6% of the 1971 U. S. consumption).[64] Put another way, it is equal to 150% of the energy used to run all U. S. farm tractors.

At the present there are few economic incentives to begin recycling and converting organic wastes. Broad-based changes will no doubt depend on the inevitably high costs of fuels and synthetic fertilizers, sufficient research rationale, the acceptance of municipal composting and sludging, and the decentralization of livestock production. Meanwhile, local efforts are possible.

ORGANIC FERTILIZER (10 tons of cow manure per acre)	CHEMICAL FERTILIZER (N=112 lbs; P=31 lbs; K=60 lbs per acre)	
HAULING AND SPREADING (Kcal/acre)	PRODUCTION (Kcal/acre)	APPLICATION (Kcal/acre)
398,475 (11 gal. gasoline)	1,415,200 (39 gal. gasoline)	36,325 (1 gal. gasoline)

Table X. Energy budget of organic and chemical fertilizer applications. Substituting cow manure for chemical fertilizers could save a potential 1.1 million kcal/acre. Adapted from Pimentel et al.[53]

DECENTRALIZED STOCK BREEDING - RESISTANCE AND DIVERSITY If genetic uniformity makes crops vulnerable to pests, then genetic diversity is the best insurance against outbreaks. There are several approaches:

a. The preservation of local plant life and wilderness ecosystems as genetic reservoirs.[69]

b. The selection and storage of crops with diverse gene pools.

c. The selection and rotation of varieties adapted to regional conditions and resistant to local as well as pandemic pests. This would establish buffer areas against widespread crop epidemics and provide more options for the success of local food production.

d. The re-integration of livestock with plant crops and the selection of animal varieties that can fend for themselves in reproduction, protect themselves from weather and disease and develop their own patterns of group behavior.[70]

Obviously these approaches are based on a dramatic decentralization of current plant and animal breeding programs and a sharp turn in research priorities from quantity to biological quality. Because the requirements for yield and crop uniformity are so ingrained in our food economy, it is difficult to imagine incentives for change, short of actual epidemics or radical economic reconstruction. Meanwhile, at the local level, community efforts in new rural areas and grass-roots research can promote the genetic diversity of crops by protecting indigenous plant life; by seeking adaptable crops from independent seed and livestock companies (especially out-crossing and non-hybrid types) and by selecting for local varieties and strains whenever possible. Cooperative gene banks may, in the future, have as much value for endemic agricultures as cooperative distribution groups have had in the past.

BIOLOGICAL CONTROLS AND DIVERSE FARMLANDS As pointed out by Rudd[13], any analysis of pesticide failure suggests three qualities to look for in alternative methods of pest control: 1) they should be capable of keeping pests at a harmless density; 2) they should not cause pests to develop resistances, and; 3) they should work with and not against the controls provided by natural enemies. Several methods fulfill these requirements in one way or another. Sex-scent attractant, reproductive hormones, sterile-male radiation, traps, etc., have all been used successfully. But by themselves these techniques are based on a strategy of *discouraging the pest.* A more permanent and stabilizing strategy in terms of closing the agroecosystem is based on *encouraging the natural enemies of pests:* their predators, parasites and diseases.

Pest enemies can be encouraged in two ways: they can be reared in large numbers under controlled

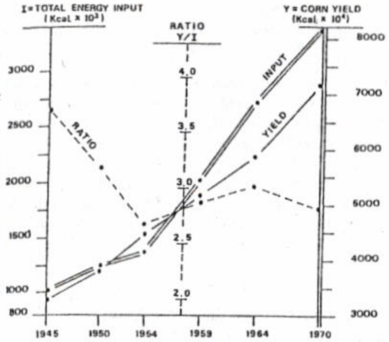


Fig. 5 Trends in the energy efficiency of U. S. corn production (1 Kcal = 3.97 BTU). Energy inputs include: labor, machinery, gasoline, NPK fertilizer production, seeds, irrigation, pesticides, crop drying, electricity and transportation. Note that, on scale, figures for yields are ten times greater than those for energy inputs. Adapted from Pimentel et al.[53]

cultivation, but it does not lead to improvements in the efficiency of energy use.[56]

Thus, despite the high yields of modern farm technology, there does not appear to be an obvious net return of energy to society. In effect, the benefits of solar energy fixed in our foods are offset by the subsidy of fossil fuel energy needed to produce them.

Obviously there are strong implications in the fact that the principal raw material of modern agriculture

COMMODITY	CROP ENERGY VALUE GAL GASOLINE/TON	PRIMARY ENERGY INPUTS* GAL GASOLINE/TON	RATIO: CROP ENERGY/ INPUT ENERGY
Field Crops			
Barley	101.9	15.4	6.6
Corn	107.5	46.5	2.3
Rice	106.0	41.5	2.6
Sorghum	97.0	38.3	2.5
Wheat	97.2	18.1	5.4
Raw Vegetables	12.3	15.9	.77
Range	(5.0 - 35.9)	(8.4 - 65.9)	
Raw Fruits	15.7	28.8	.54
Range	(11.1 - 19.6)	(12.9 - 53.1)	
AVERAGE OF ALL RAW FOODS	29.9	21.9	1.36
Canned Vegetables	17.1	67.1	.25
Range	(6.1 - 28.0)	(36.7 - 97.3)	
Canned Fruits	12.3	48.7	.25
Range	(8.8 - 14.9)	(35.9 - 57.9)	
Frozen Vegetables	14.8	68.6	.22
Range	(6.4 - 29.8)	(52.2 - 92.0)	
Dried Fruits & Nuts	142.4	222.8	
Range	(93.6 - 170.9)	(133.4 - 322.4)	.63
AVERAGE OF ALL PROCESSED RAW FOODS	45.5	97.2	.47

Table VII. Energy efficiencies of different crops produced in California, 1972. Adapted from [54]. *Inputs include machines (planting, culture, harvest, transport, storage, processing); fertilizers (production, transport, handling, application); irrigation; farm vehicles; frost protection; airplanes.

is a dwindling, non-renewable resource. For one thing, there is the relationship between the inevitable rise in fossil fuel prices and the availability of food... especially products that require high energy inputs like processed foods and animal protein.[j] In fact, meat may become so expensive in the future that it will probably be replaced entirely by vegetable protein in the diets of many people. But vegetable protein may also become hard to get as the United States implements its basic 1970's foreign policy, which uses domestic grains and legumes to reduce the balance of payments and to barter for oil and natural gas in foreign trade. Inevitably, the energy crisis will lower the quality of food for most people, especially the poor. For others, these changes could precipitate a renewed interest in urban "Victory Gardens" and microfarms and provide an impetus to develop food cooperatives and local food economies linking the inner city to suburbia.

On the positive side, the strain of fuel shortages on food production may ultimately stimulate a broad-based approach to the development of ecologically-sound and energy-saving approaches to agriculture. The above might include incentives for using cropping patterns that limit the scale of mechanization, the utilization of renewable energy resources (solar, wind, organic fuels) to supplement rural power needs, increased emphasis on integrated pest control, organic waste recycling and other low-chemical farming practices.[k]

AGRICULTURAL RESEARCH: RESTRICTING THE OPTIONS Unfortunately, little has been done to develop techniques to make farms more practical and productive within an ecological, renewable-energy framework. The agricultural research establishment continues to develop, promote and extend chemical, energy-consuming technologies in the name of pragmatism and economic "efficiency." The National Academy of Sciences has criticized the USDA and various state research institutions for supporting "pedestrian and inefficient work," for being guided by policies "repressive to the vitality of science," "detrimental to the interests of agriculture," and for neglecting basic research.[58] This last criticism is especially telling.

j. In the U. S. it takes about 6500 Kcal. to produce one pound of beef or about 38,000Kcal per pound of protein.[57] In contrast, one pound of corn fed to the cattle requires from 514 Kcal[54] to 639 Kcal[53] to produce depending on the extent of energy inputs one plugs in.

k. In 1970, the proportion of energy inputs into U. S. corn production included the following: chemical fertilizers, 36%; pesticides, 1%; maintenance and operation of farm machinery, 42%; electricity, 11%; labor, seeds, irrigation, crop drying and transportation, 10%.[53]

since it points to the inability of conventional agricultural research to investigate and promote alternative methods of farming which stem from *basic* ecological principles:

(the antitheoritical bias of agricultural science) is reinforced by the search for marketable products (mostly chemical) as the central strategy for improvement of agriculture.... and by a narrow acceptance of the present structure of agriculture as a given condition which restricts options. For example, the consideration of mixed plantings is inhibited by the present design of farm machinery. Therefore, research into the ecology of mixed sowing only makes sense as part of a broader program that must include an engineering effort to redesign the machines.[59]

In other words, much of agricultural research is heavily biased and restricted by a narrow set of technological assumptions. In contrast, a true agricultural science is not guided exclusively by economic restrictions, but also by biological realities; it examines the potentials of food production from an ecological point of view... from a self-sustaining point of view, realizing that applied ecology is nothing more than long-term economics.

ECOSYSTEM FARMING: A SELF-SUSTAINING TECHNOLOGY

When the practice of industrial agriculture is interpreted in the light of current knowledge of ecosystems, a picture emerges which suggests that the future dependability of such agriculture is in grave doubt.

– *Institute of Ecology*
Man in the Living Environment

Agricultural systems are essentially artificial communities of domesticated plants and animals. In order to understand the use of ecological tools in agriculture, we might first consider briefly the ecological characteristics of natural plant and animal communities. These characteristics can then be used as models for our agriculture.

MODELS IN NATURAL ECOSYSTEMS Although not always obvious, wildlife communities have a biological integrity. Not only do particular groups of creatures usually live in a particular habitat, but the habitat is modified and new habitats created by the living community itself. The two dynamics evolve to form a self-sufficient habitat or "ecosystem." We have, for example, a grassland ecosystem, a forest ecosystem, a pond ecosystem.... an agricultural ecosystem.

The sun provides the energy for the running of ecosystems. This energy is stored by green plants and passed on through a food chain of plant-eaters and flesh-eaters. Wastes and dead bodies become food for microbes which decompose complex organic matter into simple materials that can be used again by plants. Available food energy is gradually lost as work and metabolic heat at each link along the food chain. *In ecosystems, then, matter cycles and energy flows.*

For the efficient conversion of matter and energy back into the life cycle, ecosystems are held together by very diverse but specific kinds of plant/animal relationships. Since energy and matter are lost as they pass along the food chain, plants are more abundant than plant-eaters and these, in turn, are more numerous than flesh-eaters. Since most animals have a variable diet, food chains intermingle in an ecosystem and form a complex food "web." Generally speaking, the more complex the food web, the less likely it is that a natural disturbance or outbreak will alter the integrity of the ecosystem or cause individual members to become extinct. Hence, in natural ecosystems, there is a strong relationship between biological diversity and internal stability.

Other important characteristics of natural ecosystems have been described by Pimentel:[60]

a. Animal populations in natural biotic communities are relatively stable; outbreaks.... are generally rare.

b. Most species are rare in relative numbers.

c. The majority of animals feed on living matter as opposed to non-living... Although many animals are associated with dead matter, most of these animals.... are feeding on microbes ... present in the decaying matter.

d. Population outbreaks frequently occur with newly introduced animal species. The plant hosts on which the newly introduced animal is feeding often lack resistance to it.

e. Resistance factors which limit the feeding of animals on host plants are common in nature, including spines, toxins, growth inhibitors, etc.

THE FARM AS AN ECOSYSTEM Farmlands, on the other hand, are artificial ecosystems. They reflect

important differences from the workings of natural ecosystems:

a. Agro-ecosystems are open communities of limited duration. Because of cultivation and harvest, there is little opportunity for plant nutrients to be recycled. Natural ecosystems, however, are nearly closed communities since plants feed on the decayed bits of their recycled predecessors.

b. Cultivated plants and animals are particularly susceptible to attack from pests and diseases; most natural resistance has been bred out of them in favor of productivity and palatability.

c. Demands for agricultural efficiency are really demands for biological simplicity and uniformity. Hence, agro-ecosystems contain only a few species of plants and animals which are substituted for the more complex network of the wildlife community. Strong interactions often develop among these few species and their associated competitors and predators. The system is simple and unstable or easily disturbed. This is why pest populations are often larger in monocultures than in mixed-species stands.[61-63] This "simplicity" of agro-ecosystems takes on several forms: (1) *Crop Simplicity:* fields are usually planted to a single kind of crop, occasionally two (intercropping), very rarely several (mixed stands). Herbicides eliminate weeds so that only one crop prevails. (2) *Genetic Simplicity:* crops and livestock are usually of one high-yielding variety or inbred line of hybrid stock that often, in the name of production, forsakes disease resistance and adaptability. (3) *Structural Simplicity:* The farm landscape is structurally simple, without hedgerows, trees, weeds and other refuges of beneficial animals to interfere with efficiency. (4) *Ecological Simplicity:* the farm ecosystem is simple with respect to the number of relationships among links in the food chain. For example, in (1) above, or when livestock are moved to feeding lots so that manure can't be recycled locally, or when natural enemies of pests are eliminated by indiscriminate pesticides, etc., the farm is made unstable in an ecological sense and requires large inputs of synthetic chemical energy to replace the biological energy that usually maintains balance and stability.

Generally speaking, farming practices of fertilizing soils and controlling pests fall on a spectrum between the chemical and ecological extremes. Today, practically all farming is at the chemical extreme. But, as I have tried to show, there is a growing imperative for ecological alternatives in farming which foster a more stable and closed agro-ecosystem.

ORGANIC WASTE RECYCLING AND CONVERSION In 1971, the cities spent over $3.5 billion to collect and dispose of solid wastes. Next to schools and roads, this was the costliest of all public services. In that same year, the U. S. generated about 880 million tons of organic waste solids (Table VIII). Less than 0.1% of this was sold commercially as compost, dried manure and processed sewage sludge. A similar amount was used by farmers as fertilizer and soil conditioner (Table IX).

Source	Waste Generated	Readily Collectable
AGRICULTURE		
Crops & food waste	390	22.6
Manure	200	26.0
URBAN		
Refuse	129	71.0
Municipal sewage solids	12	1.5
INDUSTRIAL WASTES	44	5.2
LOGGING & WOOD MANUFACTURING	55	5.0
MISCELLANEOUS	50	5.0
TOTAL	880	136.3

Table VIII. Amounts (1 million tons) of dry, ash-free organic wastes produced in the United States in 1971. Adopted from U.S. Bureau of Mines (64).

Unfortunately, most organic waste is not returned to the land but is either burned or dumped into oceans, rivers and landfills. This unwillingness to close a basic ecological cycle occurs at both ends of the human food chain. On farmlands, the centralization of livestock production has produced a waste "problem" instead of a waste resource, while the expediencies of a few salt fertilizers have replaced the traditional patterns of crop rotation, green manuring and lea farming.

In the cities, the return of organic wastes to farmlands is hindered by the attitude that municipal composting is economically inefficient and therefore not a viable alternative to simple dumping and burning.[66,67] True,

	1967	1968	1969
1. DRIED BLOOD	2154	2173	2251
2. CASTOR POMACE	2924	2584	1626
3. COMPOST	35,171	41,284	19,472
4. COTTONSEED MEAL	3,920	2,522	5,416
5. DRIED MANURE	366,013	363,418	350,557
6. SEWAGE SLUDGE	124,681	138,355	131,062
7. TANKAGE	9,407	6,606	6,732
8. OTHER	9,709	14,005	18,601
	553,979	570,947	535,717

Table IX. Natural Organic Materials Used (in tons) as Fertilizers in U.S. Agriculture. From Statistical Reporting Service, USDA[65]

Speaking generally, interplanting the farm landscape with trees, hedgerows and other perennial stands, together with rotations,[1] strip cropping and mixed stands will serve to promote stability and effective natural pest control. But diverse landscapes and mixed farming methods *per se* will not create stability. Sometimes diversity decreases pest damage, other times it may increase it. The web of possible plant/animal relationships is immeasurably complex, and each situation and crop ecosystem is unique. In other words, the right kind of diversity must be established, and we can only know that by practical experience in local areas and ecological studies of the agricultural environment.

There is yet another level of ecological complexity in agriculture that has tremendous potential on a decentralized scale, but which is yet to be fully explored. This is the idea of the polyculture farm. The concept is borrowed from practices of the rice-vegetable-fish-livestock economies of southern and eastern Asia. Adapted to current information about ecological principles and a holistic science, modern polyculture farms would link several artificial ecosystems in a balanced and relatively self-sufficient complex of renewable energy systems, mixed crops, aquaculture plus livestock, and insect husbandry (Fig. 7). At the present, several grassroots groups in America and Europe are investigating various ways to integrate renewable food and energy systems into endemic polyculture schemes.

1. There is some debate on the long-term effects of continuous rotations. From 50 years of 6 year rotations (corn, oats, clover and timothy), Albrecht (79) noted that the problem of returning fertility to exhausted soils may be easier if one used one crop and grew it continuously: "That procedure would seem a logical one when the evidence shows that rotations were the quickest way of mining the soil by calling in several different crops in rapid sequence, each for its different and added exploitive effects".

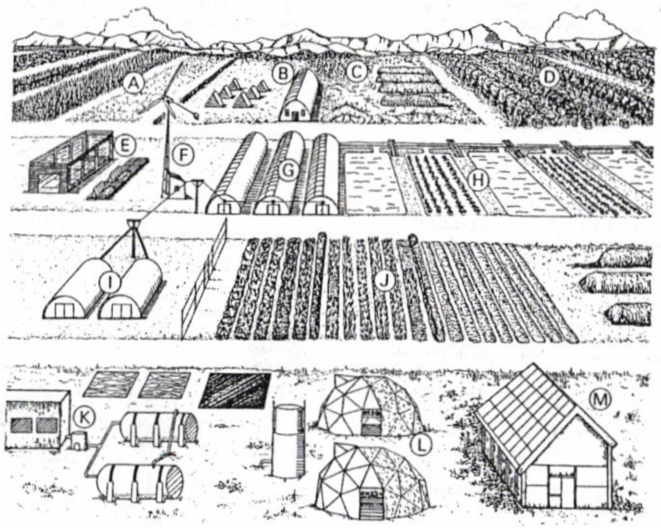


Fig. 7 An idealized polyculture farm and research center. A=Grains, green manure and forage crops. B=Solar grain-drying structures. C=Windrow compost piles on fallow section. D=Diverse, multi-storied orchards with undergrowth of refuge plants and green manure crops. E=Fish=food stocks; aquaculture insectary and worm cultures. F=Wind generator. G=Solar-heated Quonsets for rearing warm-water fishes and crustaceans. H=Outdoor fish ponds and row-crop fields. I=Agriculture insectary for rearing beneficial insects. J=Experimental vegetable/herb/flower/weed beds for investigating diverse cropping systems. K=Poultry shelter with methane digesters, sludge ponds and gas storage tanks. L=Dome-greenhouses. M=Solar-heated laboratory/homesite.

munities and regions are being abandoned. Changing land-use patterns reduce the diversity and distribution of germ plasm further by destroying habitats of endemic wild plants. This combined loss of genetic diversity reduces the gene pool from which plant breeders can choose to breed future varieties resistant to future diseases. Such a genetic reserve is important because the evolutionary contest between disease microbes and cultivated stocks is a continuous exchange of mutual adaptations; short-lived microbes mutate and recombine to new diseases while longer-lived crops struggle to adapt resistance.[h] Likewise, the development of resistant varieties of crops is a continuous process and needs a diverse genetic base from which to operate. Unfortunately, a large proportion of the genes of old varieties has been discarded; the new varieties represent only a fraction of the gene pool once planted.[i] This loss, although not well publicized and understood by the public, has very serious consequences for the availability of future food supplies.

2. Most high-yield crops encourage the use of pesticides and synthetic fertilizers; in fact, they have actually been developed in concert with agricultural chemicals. The new varieties appear to be prone to pest attack (e.g., the dwarf IR-8 rice, the "backbone" of the Green Revolution, is susceptible to sheath blight and the brown leafhopper). This means that farmers are forced to use pesticides, including herbicides, to protect their high yields and to stretch production potential. In addition, high-yield varieties are productive only because they are responsive to heavy doses of chemical fertilizers; they are ineffective without this input. Thus, the abundance of high-yield crops has to be weighed against the hazards of the chemicals needed to make them so productive.

3. Planting large areas to the same kind of crop encourages the spread of disease and pest outbreaks. When the monocultures are extended over broad geographic areas, as they are today in the United States, the potential for crop epidemics is compounded. This is precisely the condition that precipitated the great Irish potato famine of the 1840's and the U. S. corn leaf blight in the early 1970's when over 15% of the total U. S. corn crop was destroyed. These and other examples show that crop monocultures and genetic uniformity actually invite crop diseases, increased pesticide use and the potential for higher food costs and food shortages.

Unfortunately, the market economy rather than common sense determines whether a new crop variety is used. The farmer requires uniform crops for tending and mechanical harvesting. The middlemen require uniformity for processing and mass merchandising. The competitive market permits no alternatives, in spite of the fact that our dependence on a narrow genetic base for our food supply destroys genetic reserves and encourages polluting inputs and crop epidemics. This fundamental dilemma was brought to focus by the 1970 U. S. corn leaf blight and was described in a report issued by the National Academy of Sciences, which concluded that:

a) .... most major crops are impressively uniform genetically and impressively vulnerable. b) This uniformity derives from powerful economic and legislative forces. c).... increasing vulnerability to epidemics is not likely to generate automatically self-correcting tendencies in the marketplace.[47]

FARM ENERGY, RISING FOOD COSTS AND CHANGING DIETS A characteristic of chemical farming is the close relationship between pesticides and synthetic salt-fertilizers. These two technologies were developed together and are interdependent. As noted earlier, the use of agricultural chemicals, together with crops geared genetically to their use, have forced the farmer onto a treadmill of chemical routines and resources. (Fig. 4)

h. For instance, many patterns of human history reflect the gradual recurrence of wheat rust epidemics. Today, the survival of a given wheat variety in the Pacific Northwest is about 5 years (47), before a disease will force development of a new resistant variety.

i. As to the large world collections of germ plasm stored for future use at the National Seed Storage Laboratory, one agronomist writes: "If you are willing to entrust the fate of mankind to these collections, you are living in a fool's paradise... (they are) enormously redundant... some races are hardly represented at all and the wild and weedy gene pools are conspicuously missing. In no collection is there an adequate sampling of the spontaneous races that are the most likely sources of disease and pest resistance. On the whole, the collections we have are grossly inadequate for the burden they will have to bear."[51]

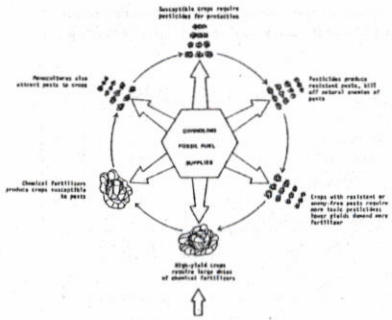


Fig. 4 The treadmill of chemical dependence fostered by the high-energy technologies of modern agriculture and nurtured by a series of ecological backlashes.

TABLE V. Fossil Fuel Requirements for different aspects of agriculture. Data are for California (1972). From Cervinca et. al. [54]

CATEGORY	ENERGY SOURCE (IN MILLIONS OF UNITS)						TOTAL
	NATURAL GAS THERMS	ELECTRICITY KWH	DIESEL FUEL GAL.	GASOLINE GAL.	LP GAS PROPANE BUTANE GAL.	AVIATION FUEL GAL.	MILLION BBLS CRUDE OIL
Field crops	364.784	464.681	96.400	19.477	2.381	--	9.34
Vegetables	165.999	358.193	38.792	25.031	4.441	--	4.62
Fruits and nuts	127.168	410.773	26.158	12.602	3.296	--	3.39
Livestock	107.111	1,460.966	46.443	7.813	12.261	--	4.19
Irrigation	40.618	7,177.441	6.531	.487	4.521	--	5.16
Fertilizers	305.748	579.362	6.738	3.529	1.114	--	5.87
Frost protection	---	40.501	60.003	6.854	.904	--	1.63
Greenhouses	102.700	83.427	---	---	---	--	1.82
Agr. aircraft	---	---	1.072	1.607	---	8.994	0.25
Vehicles (farm use)	---	---	10.447	117.798	---	--	2.77
Others	---	---	---	---	23.711	--	0.39
TOTAL	1,214.128	10,575.344	292.584	195.198	52.629	8.994	
EQUIVALENT (Million bbls crude oil)	20.93	6.21	7.06	4.17	0.86	0.19	39.41

The chemical treadmill is only part of the regime of gas and oil technology that now fuels the fields and cares for crops. Virtually all of the agricultural tools used today depend on fossil fuel energy in one form or another (Table V). With possible fuel shortages, whether real or political, there seems little doubt that our present euphoria about farm production is ill-founded and that the energy crisis will have increasing effects on the production, consumption and price of food.

Agriculture, of course, is just the starting point of a large food industry that includes production, processing, transportation, marketing, plus domestic storage and cooking. In 1963, these food-related activities consumed about 12% of the total U. S. energy budget, or the equivalent of about 240 gallons of gasoline per person (Table VI). Assuming that one person eats about one million kilocalories of food energy per year, or about 29 gallons of gasoline, it seems that our notions about food as an energy supplier are largely an illusion.

There is some evidence that agriculture itself has become an energy sink. Pimentel[53] has shown that, with regards to U. S. corn production, the ratio of energy in yields to energy in production inputs ("production efficiency") has started to decline in recent years (Fig. 5). This decline has a profound effect on other food industries since corn supplies livestock feed as well as oil and food.

The production efficiencies of other raw foods are listed in Table VII. Although there is considerable variation in energy intensiveness among different crops, on the average, most seem to use about as much energy for production as they provide for sustenance.[54,55]

Viewed in terms of an energy budget, then, modern agriculture does not seem so efficient. In fact, it may be less efficient than more "primitive" forms of agriculture:

> .... modern agriculture based on the exhaustion of fossil fuels may produce more than hand

Source	Million BTU's	Heat Equivalent Gal. Gasoline	% of Total
Agriculture	5.8	43.0	18
Food Processing	78.5	78.5	33
Transportation	0.9	6.7	3
Wholesale & Retail Trade	5.2	38.5	16
Domestic (Storing, Preparing, Transportating)	9.9	73.3	30
TOTAL	32.4 million BTU's per person per year	240 gallons of gasoline	100.0%

Table VI. Distribution of total per capita energy requirements for food consumption in the United States (1963). Adapted from Hirst.[52]

conditions (insectaries) and released at strategic times into crop areas. Alternatively, crop patterns and local environment can be modified so as to favor the life histories of beneficial insects already in the fields. Changes might include the cultivation of companion crops, the maintenance of uncultivated areas or the establishment of permanent refuge habitats. There are several ways to improve the ecological stability of croplands; only a few specific relationships will be mentioned here for illustration:

a. *Flower-crops:* The nectar and pollen of many flowers provide food for adult beneficial insects.[71,72] In orchards, for example, wildflowers can nurture populations of parasitic wasps and thereby reduce certain pests.[72,73] Research in Russia has shown that when the weed *Phacelia* was planted in orchards, a parasite of the tree's scale pest thrived in the orchard by subsisting on the nectar of the weed. When the population of the pest increased to dangerous levels, the parasite was in sufficient numbers to control the pest, thus avoiding the unpredictable lag period that normally occurs between the appearance of a pest and its natural enemy. Another Russian study showed that, when small plots of umbellifers were planted near vegetable fields in a ratio of 1 flower plant:400 crop plants, up to 94% of the cabbage cutworms were parasitized. Flowers of crop-plants such as brassicas, legumes and sunflowers can also serve as alternative food sources for beneficial insects.

b. *Repellent crops:* Most insects are selective as to the kinds of plants they eat. It is generally held that insects are attracted to the odors of "secondary" substances in plants rather than to the food value of the plant itself.[74]

Experiments have shown that odors given off by aromatic plants interplanted with crops can interfere with the feeding behavior of pests by masking the attracting odor of the crops.[75] This means that certain kinds of plant diversity *per se* may have a profound effect on pests over and above that conferred by natural enemies. Repellent crops so far described include various pungent vegetables (*Solanum, Allium*) and aromatic herbs (*Labiatae, Compositae and Umbelliferae*).

c. *Trap crops:* Some plants can be used to attract pests away from the main crop. With careful monitoring these "trap" crops can also serve as insectaries for natural enemies. For example, when alfalfa strips were interplanted with fields of cotton, the Lygus bug (a serious pest in California) migrated away from the cotton and into the alfalfa.[77] With their concentrations of Lygus bugs, the alfalfa plots then provided a food source for several predatory insects in the area. Trap crops of alfalfa may also have applications in walnut and citrus orchards and bean fields. In the coastal climate of California, brussels sprouts, which attract large numbers of aphids, can function as overwintering insectaries for parasitic wasps. When aphids attack other crops in the spring, wasp populations, having fed on aphids during the lean winter, are large enough to respond quickly and control the aphids.

d. *Hedgerows and Shelter Belts:* For centuries hedgerows have been planted between field crops to slow down winds and thus reduce wind erosion and improve microclimates. The presence of uncultivated land near cultivated fields also has a profound effect on the distribution and abundance of insects associated with crops. Wild plant stands can provide alternative food and refuge for pests and their natural enemies alike. In fact, almost every advantage offered to the one is, to some degree, available to the other. Hence it is not always clear whether uncultivated land is beneficial or harmful to pest control. However, in England, where much farming is done near wild vegetation, pest problems are generally less severe than in the United States where monoculture farming persists.[78]

Many other kinds of plant relationships can be cultivated to advantage. Some "component" species probably serve more than one beneficial function. Repellent herbs, for example, also produce food-rich flower heads, as do many trap crops. Garden models (Fig. 6) exist for a variety of mixed cropping schemes,[79] and these undoubtedly could be tested and applied on a larger scale. Interest, however, will probably remain focused on monocultures until the "costs" of pesticides and poor farm management exceed the "costs" of ecological designs.

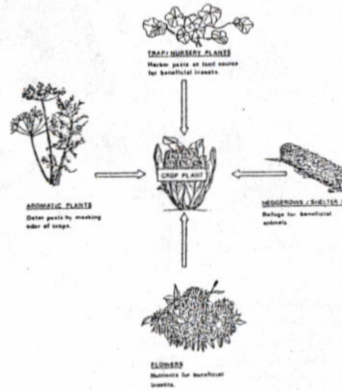


Fig. 6 Some possible components and plant interactions of a diverse cropping system, based on a garden model of "companion planting" arrangements.

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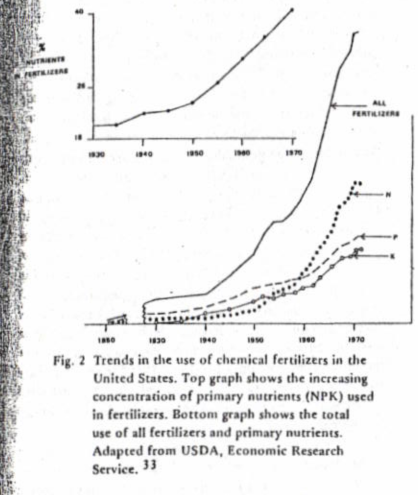


Fig. 2 Trends in the use of chemical fertilizers in the United States. Top graph shows the increasing concentration of primary nutrients (NPK) used in fertilizers. Bottom graph shows the total use of all fertilizers and primary nutrients. Adapted from USDA, Economic Research Service. 33

Similar advances with nitrogen and potassium compounds provided the impetus for the complete substitution of synthetic fertilizers for natural fertilizers. By 1954, organic materials accounted for less than 3% of the total fertilizers used in U. S. agriculture. Further trends in the adoption of chemical fertilizers have been:

1. The rate of use has increased steadily since 1850 and even more rapidly since the beginning of World War II. Most forecasts predict a continued increase in use through the 1980's.

2. Since 1959, nitrogen has been the primary nutrient fed to U. S. crops (Fig. 2). Use has increased from 0.5 million tons in 1945 to 6.6 million tons in 1970. By 1980, U. S. Agriculture will be using over 11 million tons or about 10% of the total world consumption.[34]

3. New developments in production technology have increased the purity of chemical fertilizers and hence the concentrations at which they are used (Fig. 2). For example, nitrogen is being used less in mixed forms (combined with other nutrients) and more in concentrated forms like anhydrous ammonia, i. e., liquified ammonia gas (Fig. 3).

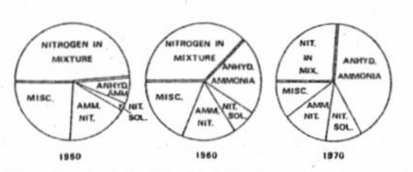


Fig. 3 Changing proportions of mixed and concentrated nitrogen fertilizer being used in U. S. agriculture. Concentrated forms include anhydrous ammonia, nitrogen solutions, ammonium nitrate and other miscellaneous types (aqua ammonia, urea, ammonium sulfate). Adapted from Tennessee Valley Authority, National Fertilizer Development Center.[35]

4. In 1970, about 70% of all chemical fertilizers used were applied to four crops: corn (95% of the corn acres received fertilizer); cotton (72%); wheat (59%), and soybeans (29%). For most crops, the proportion of acres receiving applications of chemical fertilizers increases each year.[33]

5. Cheapness and ease of shipment have made synthetic fertilizers most attractive. Still, prices appeared to bottom out around 1969. Because fertilizer production is so heavily geared to fossil fuel inputs, prices will certainly rise sharply in the coming years.[36] For example, the cost of natural gas as a raw material (source of hydrogen) and fuel (to fix atmospheric nitrogen) accounts for 60% of the manufacturing costs of ammonia which now supplies about 90% of all fertilizer nitrogen. Phosphorous and potassium fertilizer costs will also increase since they require fossil fuel energy for manufacturing and for the production and mining of raw materials (e. g., phosphoric and sulfuric acids, phosphate and potash rocks).

6. Future increases in chemical fertilizers are likely to occur on low fertilizer-using crops and areas, since many of the high fertilizer-using crops, such as corn, are approaching the maximum profitable rate of application.[37]

Because chemical fertilizers are highly soluble salts, used in large amounts they over-stimulate natural cycles and exaggerate amounts of certain chemicals in the environment. For example, before large-scale manufacturing of chemical fertilizers, there was a balance between nitrogen removed from the atmosphere by natural fixation and nitrogen returned to the atmosphere by natural denitrification. Today, due to extensive use of nitrogen fertilizers, there may be an accumulation of nearly 10 million tons per year of fixed nitrogen compounds in the biosphere.[38]

One consequence of this build-up of fertilizer salts has been the enrichment of local water reserves and the destruction of aquatic animals by eutrophication.[f] Another has been the accumulation of toxic forms of nitrogen in water supplies and crops. There are two major kinds of nitrogen toxicity: 1) The chemical reaction of nitrites (NO_2) with blood hemoglobin which impairs the circulation of oxygen in the blood

f. Some claim that carbon, rather than nitrogen or phosphorous is the primary cause of eutrophication. Although there is evidence to the contrary, this notion has been encouraged by the soap industry which has high stakes in the effects of phosphorous on water supplies.

(methemoglobin), or causes vitamin deficiencies. Nitrite concentration is common in some fodder crops where it poisons livestock, or in vegetables of the brassica or spinach family where it constitutes a real health hazard, especially in baby foods.[39,40] 2) Nitrites may react with amines in the body to form nitrosamines and related nitrosaminides. These compounds are known to induce cancer.[41] Concern that increased use of nitrogen fertilizer may be linked with the growing incidence of cancer in modern society has been expressed by even the medical establishment.[42]

Nitrites are found in large amounts in the soil, in crops and in ground water where nitrogen fertilizers are used extensively. Apologists for the chemical industry claim that organic wastes, industrial and domestic effluent and natural processes are more responsible for nitrate and nitrite accumulation in rural areas than fertilizers. But several studies have shown that nitrogen fertilizers can indeed percolate through soils and accumulate in local water supplies.[43-45] The long term effect of this contamination is virtually unknown, although one observation by the USDA is ominous:

> The rate of water recharge from deep percolation is so slow that the possible nitrate pollution of aquifers... will take decades. However, once nitrate gets into the aquifer, decades will be required to replace the water with low nitrate water.... By the time the trend was established, a dangerous situation could be in the making that could not be corrected in a time shorter than it took to create.[46]

Finally there is the whole controversial issue dealing with the effects of chemical fertilizers on soil fertility, as defined by the activities of soil microbes and soil animals, and the quality of crops, as defined by their nutritional value and their ability to resist diseases and pests. These questions represent fundamental gaps in traditional agricultural research and will not be dealt with here. Suffice it to say that heavy applications of chemical fertilizers may produce plants which are susceptible to attack by insect pests.[47,48] There appear to be at least three mechanisms involved: a) chemical fertilizers place metabolic stresses on plants which increase production of aromatic compounds that attract pests.[49] b) Chemical fertilizers cause plants to take up water and produce succulent growth favored by pests for shelter and food. c) The exclusive use of NPK chemical fertilizers reduces incentives for recycling organic material and trace minerals as part of a fertilizer program. Humus and trace minerals provide building blocks for plant enzymes that are important to a plant's defense mechanisms.

GENETIC EROSION AND MONOCULTURES For millenia people have domesticated wild species of plants and animals for food, selecting strains that were palatable and easy to grow. About 75 years ago genetic engineers began developing controlled breeding programs and selecting crop varieties that were resistant to some of the notorious diseases and pests which have plagued societies throughout history. These efforts continue today,[50] but they have taken a back seat to the development of a few high-yielding and uniform crops which meet the demands of mechanical harvesters and a competitive market economy. There have been three general approaches used to produce uniform strains: a) Reproduction from a single plant by vegetative cutting (e.g., potato), b) Reproduction by seeds from self-pollinating crops (e.g., lettuce, tomato, wheat, beans), c) Reproduction by seeds from controlled cross-pollination and inbreeding (e.g., hybrid corn, hybrid cucumber, hybrid onion).

On the surface, results have been spectacular. Yields of most major crops have soared,[g] and machines are now able to harvest "efficiently" and provide the finicky consumer and processor with an abundance of eye-appealing produce. But for several reasons the new genetic strategy has placed modern agriculture in perhaps its most vulnerable position by forsaking biological quality for yield and appearance:

1. The genetic base for most major crops has become dangerously narrow. As farming practices rely more and more on a few productive varieties (Table IV), the numerous strains once grown in local com-

g. For example, the yield of corn has risen from about 40 bushels/acre in 1950 to nearly 100 bushels/acre in 1970.

CROP	NUMBER OF POPULAR COMMERCIAL OR CERTIFIED VARIETIES	MAJOR VARIETIES	
		NO.	% OF CROP ACREAGE
Bean, dry	25	2	60
Bean, snap	70	3	76
Cotton	50	3	53
Corn[a]	197	6	71
Peanut	15	1	35
		3	70
Peas	50	2	96
Potato	82	4	72
Rice	14	4	65
Soybeans	62	6	56
Sugar beet	16	2	42
Sweet potato	48	1	69
		3	84
Wheat	269	5	50

TABLE IV. The extent to which a few crop varieties dominate American agriculture. Adopted from the National Academy of Sciences.[47]

a - Released public inbreds only, expressed as percentage of seed requirements

BACK TO THE LAND – FORTH TO THE LAND AND POST-INDUSTRIAL AGRICULTURE

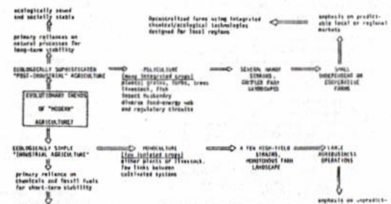
And so I believe that the Back to the Land idea is a long-term goal; no one now living will live to see it fully developed. It will be a long, slow movement... not, I hope, toward an Earthly paradise, urban or rural, but toward a new nativity of our people in the real world and in the scheme of things.

– *Wendell Berry*
The Long Way Back to the Land

Popular notions about agriculture in the future often depict great monoculture deserts, rows of high-rise livestock cages and antiseptic greenhouse complexes being nurtured by chemical robots and computers. But, as agriculture reaches its limits of space, resources and pollution, the course of agriculture will come to depend on the resolution of three fundamental issues:

1. The relationship between food production and energy. Agriculture has always depended on cheap energy: human labor, beasts of burden, or oil. As the world's fossil fuel reserves become scarce on a seller's market, industrial agriculture will be left with two alternatives... nuclear power and solar energy (meaning direct solar rays, wind generated by them and, indirectly, organic fuels). The use of nuclear energy in agriculture would accelerate the current monopoly of farmlands by corporations, industry and their esoteric technologies... it would take farming out of the hands of farmers once and for all. But the thought of radio-active wastes in the human food chain summons the hope that a solar energy technology for agriculture will return to agriculture its proper function... transforming mutation of the sun's power for human needs. Since solar energy is readily available and easily devised (compared to nuclear power) its application to farming practices will tend to keep agriculture in the hands of farmers and pace down the acceleration and monopoly of the high-energy farm factory. That is, a decentralized solar economy for agriculture would extend the role of the rural community from an independent social order and keep it from degenerating into a total extension of the industrial one.

2. The relationship between science and human needs. In recent years, conventional science has come under increasing attack for the moral implications of its basic inquiries and the long-term significance of its applied tools. There has been relatively little criticism of the agricultural sciences along these lines since the total external costs of modern farming practices are just beginning to surface with a broad impact. In light of these "costs" what is needed are ecological tools that keep farming productive and the economic incentives that make them practical. To do this, new questions have to be asked in the laboratories and, most importantly, in the fields. What are the long-term effects of farm chemicals on human health, and what are the options? How can diversified farms be integrated with adequate markets? How can renewable energy sources be integrated with crop production? Such questions reflect an agricultural science with a holistic and extended approach; that is a science which controls the questions being asked. Most likely new-farm research will be carried out at the local level, for local purposes. New models for a land-based agriculture are not apt to come from organized science, but from the ability of local groups to use their own kind of inquiry.



Evolutionary Trends of Modern Agriculture

3. The relationship between people and land. During the last century, the United States has experienced one of the largest internal migrations in human history – from the farm to the city. But in our flight to convenience there is every indication that the changing relationship between people and land as well as the concentration of people into urban centers are at the heart of basic social problems. As a result, people are again looking to the land. In the 50's and 60's, a federal network of roads and reservoirs made it possible for people to retrace old trails to America's heartland with industry, recreation, second homes and retirement communities. But beyond this... way beyond... is the need to make productive land available to all people who wish to farm. Since 1967, the value of farmland has increased by nearly 80% and there is no end in sight. As long as there is speculation and land monopolies, agriculture will continue its course to the industrial state, and all visions of a self-sustaining agriculture will lie fallow in our hopes and dreams.

– *Richard Merrill*

As I mention in the article describing New Alchemy's Ark, food production in America, unlike agriculture in many regions of the world, is highly energy-intensive and dependent upon huge oil inputs. The disparity, in energetic terms, between U. S. agriculture and that of peoples with sensitive gardening approaches to farming is as high as 25:1 or even 40:1 in favor of the latter. This is a side of the green revolution its proponents rarely discuss. Some farmers in places like Malaysia and New Guinea are capable of producing twenty calories of food for one calorie of energy expended; we use five calories or more of energy to produce one calorie of food on the American table. We are hooked on high energy modes of food production and because this fact has been ignored, a population has been placed out on a limb.

Energy is used in a variety of ways in the production of food. There is the manufacture of necessary modern machinery and equipment, then transportation, storage, drying, processing and packaging, not to mention a number of other inputs including advertising, all of which require fossil fuels for their sustenance. To make things worse, our agricultural lands have been so badly treated and misunderstood in ecological terms that a whole arsenal of chemicals is required to fend off pests, kill weeds, check diseases and provide plants with nutrients. These chemicals are all ultimately dependent upon fossil fuels in their manufacture and many are petroleum derivatives. Herbicides, pesticides, fungicides and fertilizers can be purchased by farmers only if oil remains cheap and readily available. The manufacture of both nitrate and phosphate for fertilizer requires excessive amounts of energy, surpassed on a per unit output basis by few other industries, such as aluminum.

Industrialized agriculture cannot get along without these inputs, as many alternative paths have been closed behind us. We are increasingly paying the price for treating land as a commodity rather than as something alive and sacred. When the oil tinkers tinker, they could unleash events which will bring real troubles to the farms and the larders of the country.

Already there are ripples as a result of the mini-crisis. In the fall of 1973 a number of farmers were finding it difficult to get enough gas to dry their high-yield corns. The problem is at once ironic and typical; the new corns are harvested "wet", having a higher water content at harvest time than older varieties. Spoilage results if they are not artificially dried.

But the worst problems in the food production chain are in the industrial linkages. Cutbacks in availability of oil to petrochemical industries, as well as increasing prices, could put a squeeze on pesticides, herbicides and fungicides. If these products "short fall" on farm lands, there could be a serious drop in production of foods. Shifts to biological farming methods can and must take place, but they cannot be rapid, as they usually take many years to be effected and require more intensive techniques and planting strategies, not to mention a wholly different attitude toward agriculture. One petrochemical industry spokesman predicted a sixty-five billion dollar drop in his industry and 1.6 million jobs lost in 1974. While he was no doubt exaggerating the magnitude of the problem for ends not yet clear, there is little doubt that shortages and price increases of an unprecedented nature are taking place and that these will inevitably affect farm inputs. One example will suffice to make my point. Within a period of a few weeks, the price of phosphates from Morocco, a major phosphate producer, rose from $14 to $42 a ton.

This whole scenario, it must be remembered, has to be seen against the backdrop of a world without substantial food reserves. Nations with faltering industrialized agricultures cannot be bailed out, short of war or blackmail on their part. If a pseudo-crisis can induce strains into a system, then a genuine reduction in fuel availability could seriously dislocate a modern society.

A real energy crunch is on the way. At this point I should like to bring forth some of the arguments of Howard Odum, one of the fathers of ecology in America. Odum's view of the future is one of the most apt, and we would do well to listen carefully to his message.

For several decades Howard and his brother, Eugene Odum, have been students of Nature, trying to comprehend the primary ecological forces that underlie biological change. They have done much to advance the science of ecology, and a landmark paper by Eugene entitled, "The Strategy of Ecosystem Development", (1) chronicled the characteristics of ecosystems and environments, their use of energy and their changes over time towards more diverse, complex and stable states. Nature changes constantly. The environmental factors and man's impact on these changes are beginning to be understood. Howard Odum, in a small volume, "Environment, Power and Society", (2) attempts to apply the mechanisms of nature and the methods of ecology to an understanding of human societies and their relationships with the living world. The book, with its charts and flow diagrams and its jargon borrowed from the language of systems, has not been widely read outside the discipline of biology, although its message was very clear to those who studied its contents. Professor Odum concludes that highly industrialized societies are so out of tune with nature that their fate will be sealed within the lifetimes of many alive today.

Recently Howard Odum presented a paper to the Royal Swedish Academy of Science entitled, "Energy,

1. E. P. Odum, 1969. *The Strategy of Ecosystem Development.* Science, Vol. 164, 262-270.
2. H. T. Odum, 1971. *Environment, Power and Society.* John Wiley. 336 pp.

an integral part of our biological systems... present in our flesh, drifting in the air, flowing with the rivers and falling with the rain.[10-12] After more than a generation of unrestrained use, it is obvious that pesticides have produced..... and are still producing.... serious side effects the full consequences of which have yet to appear, but major areas of concern include:

1) *Pesticides are persistent:* Most pesticides are developed to withstand degradation by climate and microbes. Some are more persistent than others. Organophosphates break down in days or months while organochlorides can remain in the environment as poisons for years. One product of DDT.... DDE ... may be the most common and widely distributed synthetic chemical on earth.[13]

Herbicides are degraded quickly by soil microbes (i.e. soils rich with organic matter); but the by-products themselves are often toxic.[14] Chemical reports often recommend that farmers reduce their soil organic matter to make herbicides more effective! The general decrease in organic matter from U. S. farm soils suggests that herbicides will be more persistent in rural areas, in view of their increasing use.

2) *Pesticides affect public health:* There is a whole spectrum of opinion here. There are those who contend that no important human disease can be associated with pesticides.[15] There are the "objective" government reports which conclude that there is no danger of pesticides to public health but call for administrative controls and more research. The Mrak report[16] concluded that no one seems to have a clear picture of pesticide hazards in America and predicted that the number of accidents actually exceeds those reported. Others have tried to make correlations between increases in cancer, poliomyelitis, heart disease, hepatitis and other diseases and the increasing use of pesticides.[17]

Whatever one's opinion, some definite facts have been established:

a) Certain organophosphates, herbicides and other pesticides can cause cancer, birth defects and genetic mutations in animals.[16]

b) Organochlorides do accumulate in fatty tissues of livestock and humans.[18]

c) Organophosphates account for the majority of *known*[c] pesticide deaths in this country, particularly in farm workers.[19] Thus the trend to replace DDT with organophosphates has largely been a trade-off in health hazards.

d) There also seems to be a relationship between low protein diet and susceptibility to pesticide toxicity.[20] This means that pesticides may have a greater effect on poor people in rural areas. Most likely the total impact of pesticides on human health will not be realized for years to come.

c. The Mrak report (16) concluded that the majority of counties in the United States are not equipped to determine a pesticide as cause of death.

3) *Pesticides kill wildlife and jeopardize natural ecosystems:* Pesticides are poisons... they kill other things besides "pests." They are also mobile, chemically stable and have an affinity for biological systems. It is a combination of these characteristics which can cause unpredictable damage to wildlife:

Hundreds of papers have been written on the subject.[21,22]

Not well publicized, but of particular importance to agriculture is the effect that pesticides are having on honeybees.

> Large-scale monoculture, necessary for economic production... provides no continual source of pollen and nectar necessary to maintain strong colonies (of honeybees)... Use of herbicides... further reduces bee forage. The use of pesticides highly toxic to bees either weakens or destroys many colonies... This presents an impending dilemma, with a reduction of profitable bee-keeping and native pollinators on one hand and an increased need for bees for crop pollination on the other.[23]

Even pesticides of low toxicity are known to reduce pollen and nectar gathering activity of bees.[24]

Most studies of pesticides and wildlife have focused on individual species of animals, notably birds and mammals. Much more important, and far less understood, are the effects of pesticides on the integrity of natural ecosystems. In living communities the activities of each organism impinge upon and interact with the activities of other organisms sharing the same general area. If a pesticide affects only a few individual species, this still has strong implications for the living community as a whole. Persistent pesticides are like to cause the most damage, but even rapidly degrading ones may have lasting effects. One study on a grassland ecosystem concluded:

> "... although the insecticides (Sevin) remained toxic in the environment for only a few days, long-term side effects on .... arthropod density and diversity, and mammalian reproduction were demonstrated."[25]

This and other studies suggest that the most meaningful way to assess the long-term effects of pesticides on wildlife is to study the ecosystems in which they live.

The impact of pesticides on the most complex and vital land ecosystem of all... topsoil... has serious implications for agriculture. The problem of determining effects is compounded by the incredible array of life forms living in the soil and by the many physical factors which influence the persistence of pesticides in the soil. Over 500 papers exist describing experiments on the effects of pesticides on various species or groups of soil flora and fauna.[26] However, as noted above, the combined reaction of an ecosystem is a far better indicator of the effects of

pesticides than the responses of its individual members. The vigor of crops, their ability to resist diseases and pests, is dependent upon the complementary metabolisms of interacting soil microbes which provide a wide variety of major and trace nutrients to the plants.[27] Since pesticides tend to reduce the number of species of soil microbes,[28] it is also likely that they tend to upset the balanced nutritional relationship between soil and plant. The resistance of crops to pests may be the best measure of the health of a soil ecosystem and pesticides may impair this health which, in turn, will reduce the resistance.

Besides the effects of pesticide fallout on public health and natural ecosystems, there is the fact that, for ecological reasons, the single strategy of chemical control is rapidly becoming an economic disaster for agriculture. In most cases, pesticide use actually increases numbers of target pests, fosters new pests, and creates demands for new or more toxic pesticides. There are several reasons for this:

1. In many ways, pesticides free pests from control by their natural enemies (predators and parasites). First, pesticides accumulate at the end of food chains causing disproportionate mortality to the natural enemies. Second, most natural enemies have longer generation spans, are less abundant, and are slower to recover from the effects of poisons than pests. Third, natural enemies contact larger doses of pesticides than pests since they forage over greater areas in search for food. Fourth, herbicides often remove weeds which provide nourishment and refuge for beneficial insects.

2. Pesticides are not capable of "controlling" pests in the ecological and most meaningful sense of the word, i. e., over long periods of time.

3. In general, pesticides reduce biological diversity, which leads to less stable cropland ecosystems. This is a vague point to be discussed later.

4. Pests can become resistant to pesticides often to a greater degree than their natural enemies which have longer generation times and less opportunity to develop resistances through genetic adaptation. Of more than 225 species of arthropods in which resistant strains have been documented, only four are natural enemies of pests.[29]

5. Repeated pesticide treatments often produce outbreaks of secondary pests.... which would normally be kept in low numbers by natural enemies and competitors. A classic example involves the spider mites (Tetranychidae). A minor pest a quarter of a century ago, today they are the most serious insect pest affecting agriculture worldwide.[30]

These factors have precipitated a series of ecological backlashes which, in turn, have produced a definite pattern of pesticide failure and economic distress. For the farmer, the pattern usually starts with a desire for higher yields initiating intensive pesticide use on a regular schedule. Next, pest resistance compels the farmer to use larger doses or more toxic pesticides. In the meantime the numbers of old pests increase and new kinds arise. This forces the farmer to use still more pesticides at an increasing cost. Finally, the farmer exhausts his arsenal as pest problems become more severe and as spiralling costs of pesticides cut into his profits and simply ceases to be a farmer. Such economically depressed rural areas as the Rio Grande River Valley, the Lower Mississippi Valley, the Imperial and San Joaquin Valleys of California, the Canete Valley of Peru and many other once prosperous farm communities attest to the fact that the farmer has become a pawn of economic and corporate forces which have placed him on a costly pesticide treadmill. Claims by the USDA that the use of insecticides can produce a net return to the farmer of about $5.00 for every dollar invested[31] are shortsighted and grossly misleading. For over a generation, the agribusiness establishment, through economic incentives[d] and propaganda directed by the USDA and the petrochemical industry, has deluded farmers to accept pesticides with little regard for their long-term economic and ecological impact. The pattern becomes all the more absurd when we consider the many ways in which a farmer can reduce the use of pesticides without sacrificing yields.

SYNTHETIC FERTILIZERS: SALTING THE EARTH Prior to the mid-19th century, virtually all fertilizers were natural organic materials, plant and animal wastes, manures, etc. In 1840, a German chemist, Justus von Liebig, brought his findings together in a book[32] that was to change the course of western agriculture and lay the foundation for the modern chemical fertilizer industry. Simply put, Liebig's thesis was that plants could be rapidly nourished by mineral salts in solution instead of by the slowly available by-products of decaying wastes in the soil. Enormous yields could be produced simply by mixing inorganic salts of a few critical nutrients into the moist soils of farmlands. This applied especially to nitrogen, phosphorous and potassium – NPK.

The first chemical fertilizer was a phosphorous compound made by mixing sulfuric acid with bone materials.[e] The process was patented in England in 1842 and, by the end of the U. S. Civil War, tens of thousands of tons of "chemical manure" were being produced each year by the British fertilizer industry.

d. The post-war farm policy in which controls were placed on acreage instead of production forced farmers to use pesticides on their remaining land to increase yields.

e. This is an artifically refined version of the natural process in which acids from the metabolism of plant roots and soil microbes release nutrients held in reserve in the organic matter and minerals of the soil.

The Dilemma Beyond Tomorrow:

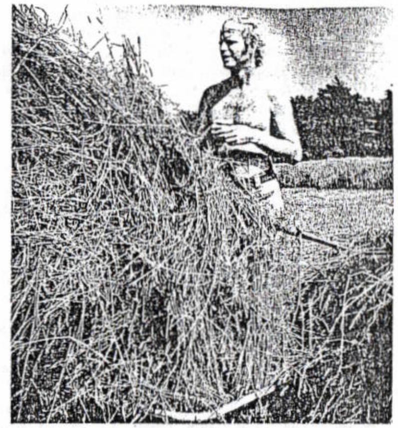


Photo by John Cressey

A Look at How the Fundamental Laws of Nature Have Been Defiled by Modern Industrial Societies Thereby Threatening the Fate of Humanity

I should like, at this point, to make four statements about energy in relation to society and then discuss them a bit more fully, beginning with the last point first.

1. Energy and its use is critical to the fate of society.

2. Our knowledge of energy is primitive and lacking in wisdom.

3. Even if the present crisis is the result of manipulatory activities, the forces which enable Oil and others to be manipulative are growing. Within our lifetimes a terrible scramble for the remaining cheap energy will take place. This almost certainly will mean war and oppression.

4. Contemporary "advanced" societies have built themselves a humpty-dumpty civilization based upon a crude understanding of nature, energetics and society. The scary thing about this is that megatinkerers, oil barons of whatever nationality, could actually collapse the whole industrial world without meaning to, merely by playing their narrow-interest power games. I shall give a brief example of what I mean, but it should not be forgotten that there are at the same time comparable events that could be, and are, occurring in many other sectors of society.

DOWN ON THE FARM, or DO WE EAT TOMORROW?

It is difficult for us to imagine stores empty of food. We have no precedent for such an event. But every time you see a gas station with an "out of gas" sign, remember that the problem is magnified down on the farm. In our mechanized society an empty tank in a tractor can quickly mean an empty shelf in a food store. The lag time can be as short as nine months. Even slight energy shortages have the potential to trigger myriad unexpected events.

sources. One of the most difficult and important ideas Odum introduces is the idea that higher quality energy must subsidize lower quality energy if the total energy output is to be maximized. The forest provides a good illustration: leaves at the top of trees transport fuels so that more shaded leaves which have less solar energy available to them get some additional energy. In this way the dim light that reaches the forest floor can be utilized even though it is of lower quality. Energy is maximized because the uppermost leaves provide a support base for lower ones which work less efficiently. High quality coals and oils, when they are inexpensive, keep goods and services cheap. These goods and services, in turn, provide the subsidy for marginal kinds of energy which would not yield much on their own. I shall elaborate on this concept when discussing the role of nuclear power in the field of energy as a whole.

Economists and technocrats are predicting that the marginal energy yielders might one day become economical. Odum claims this to be a fallacy on the grounds that they require the subsidy to exist at all. Present day marginal energy yielders represent lower quality energy sources.

It is at this point in the argument that the technologists like to point out that new technologies with greater efficiencies will be developed to reverse the equation and save us before readily available fossil fuels are exhausted. The story may not turn out so beneficently, as technologies with high end-point efficiences, (for example, engines that develop considerable power with relation to fuel requirements) actually acquire their efficiency through energy-expensive manufacture, maintenance and support structures. To produce more efficient engines requires more energy in the form of extremely complex factories. The percentage of net energy yielded may actually decrease with more efficient engines.

Environmental technologies being developed in the name of pure water and pure air also reduce the amount of net energy available to society for useful work. In relatively small and balanced human communities, pure air and water are provided by a free energy subsidy from nature. Wind, water, sun and soils work together to purify wastes and human by-products. But natural purification works only when human societies are made up of relatively small units surrounded by ecosystems such as lakes, swamps and forests that have the ability to purify and restore. When urban sprawls become too large, nature's aiding capacity is overtaxed and the free subsidy vanishes. At this point we have to maintain livable environments with costly and energy-intensive technologies like sewage plants, which include tertiary treatment facilities, waste extraction, transport systems and others. The cost to society, as a result of overshooting the natural carrying capacity of nature, is great and unhappily, is ignored by almost all.

Societies must be designed using nature as a recycling partner if they are to survive the period when high energy purification technologies can no longer draw on cheap energy sources to sustain them.

There is much discussion of new sources of energy, especially solar energy, these days. The New Alchemists and others are trying to use these energies on a small scale in more delicate and sophisticated ways. Trapping the sun's heat to provide livable climates in greenhouses and housing structures takes advantage of an energy source normally quickly lost to the atmosphere. But to see large-scale utilization of solar energy as a replacement for oils and other fuels may well prove to be an ill-founded fantasy, and to expect solar power to permit our civilization to continue on its present course is nonsense.

Solar scientists see our salvation in the large-scale manufacture of solar cells that translate the sun's energy into electricity. These cells will be mounted on vast solar collectors, some of them in space. But the solar energy striking a given unit of collecting area is very low, some 10^{-16} kilocalories per cubic centimeter. This means a tremendous amount of energy in the form of subsidies from oil and coal economies will be needed to manufacture a very large number of cells and installations for concentrating the energy and transforming it into electricity for its ultimate use. The net energy available to society may not be nearly as high as solar exponents believe.

However, plants which have an incalculable amount of surface area exposed to the sun will remain the best utilizers of the sun's energy. Their end products, food, building materials and wood fuels, represent the most effective use of the sun's energy. Plants have tiny semiconductor photo receptors based upon the same principles as have been adapted for use in solar cells. Unlike manufactured solar cells, they constitute another of nature's subsidies.

It follows, if the above notions are correct, that the whole concept of environmental technology needs re-evaluation and that those technological processes which duplicate nature's work must be seen as economic and energetic handicaps. The contemporary dilemma has been created by the establishment of high technology industrial and urban regions which have long overshot nature's healing capacity. Our attempts at correction and purification of these ecologically unsound areas will actually run down available high quality fuels at a more rapid rate. If we stick with our present system we are trapped, because we will need to use a disproportionate amount of energy to sustain a livable environment which in turn will leave less energy available for primary work. For future societies to thrive, growth limits should be set by ecosystems rather than by economic dictates which span only a few years. It is unlikely that new forms of energy, even nuclear

	FUNGICIDES[a]	HERBICIDES[b] 2,4-D[c]	HERBICIDES[b] Other Organic Herbicides	INSECTICIDES DDT	INSECTICIDES Other Organic Insecticides	INSECTICIDES Inorganic Insecticides	TOTAL (1000 tons)
1959	123.9	28.4	21.6	78.4	80.7	9.7	342.7
1960	147.5	35.1	16.1	82.1	93.4	8.3	382.5
1961	132.4	40.1	20.4	85.7	109.6	9.2	397.4
1962	98.7	40.0	35.4	83.5	119.2	7.3	384.1
1963	97.2	45.4	41.9	89.5	119.5	5.6	399.1
1964	98.2	54.0	59.2	61.9	128.1	8.1	409.5
1965	109.2	63.3	68.2	70.4	174.8	5.6	491.5
1966	120.4	--	--	70.7	205.3	5.1	
1967	112.3	80.4	124.3	51.7	196.2	3.9	568.8
1968	120.9	86.7	147.8	69.7	214.9	6.2	646.2
1969	120.8	52.0	144.7	61.6	209.4	5.2	593.7
1970	115.4	--	201.9	29.7	177.3	3.0	527.3

TABLE I. PRODUCTION OF PESTICIDES IN THE UNITED STATES (in 1000 tons). Data for inorganic pesticides are from Agricultural Statistics, USDA;[6] data for organic pesticides are from U.S. Tariff Commission Annual Report[5].

a = includes: copper sulfate and organic compounds, excludes sulfur
b = organic compounds only
c = includes esters and salts

an important discovery, not only for the grain farmer but also for the military who used 2, 4-D to destroy millions of acres of farmlands and forests in South Vietnam.[b] Today, 2, 4-D is the herbicide most produced in the United States and the one most abundantly used by American farmers.

In many ways, World War II fostered an agricultural revolution. Since the introduction of DDT, 2, 4-D and organic phosphates, U. S. production of synthetic organic pesticides has increased from 33 thousand tons of DDT and one thousand tons of 2, 4-D in 1945 to 552 thousand tons of one hundred or so different pesticides in 1968.[6] Today there are over 100 industrial firms producing about 1000 pesticide chemicals variously combined in over 50,000 registered commercial pesticides. (Table I)

Most of the public debate concerning pesticides has centered on problems associated with their uses in agriculture. However, only about 50% of the pesticides used in the United States are applied to farms (Table II); the remainder is used by government, industry and urban dwellers. In fact, suburban lawns and gardens probably receive the heaviest applications of pesticides of any land area in the United States.[8]

Pesticides, nevertheless, are used extensively on U. S. farmlands, although exact figures are unavailable. Usually records of production, sales, imports and exports give some indication of farm usage, but these

TYPE OF PESTICIDE	TOTAL USE IN U.S. 1000 tons[a]		% USED BY U.S. FARMERS	
FUNGICIDES:[b]		53		27%
HERBICIDES:[c]		114		55%
2,4-D; 2,4,5-T	43		48%	
others	71		59%	
INSECTICIDES[d]		165		57%
DDT	25		54%	
Aldrin-Toxaphene	39		68%	
Other	101		54%	
TOTAL PESTICIDE		341		51%

TABLE II. Selected pesticides used by U.S. Farmers, 1966. From U.S.D.A. Economic Research Service.[7]

a = Calculated by subtracting exports from production.
b = Excludes: sulfur and pentachlorophenol
c = Includes: plant hormones, defoliants and desiccants.
d = Includes: fumigants, rodenticides, miticides.
e = Includes: aldrin, chlordane, dieldrin, endrin, heptachlor and toxaphene.

b. In his book *Defoliation* (Ballantine Books) Thomas Whiteside notes a 1968 statement by Samual Huntington, Southeast Asia advisor to the State Department: "In an absent-minded way the United States in Vietnam may have stumbled upon the answer to 'wars of National Liberation' ... forced draft, urbanization and modernization which rapidly brings the country in question out of the phase in which a rural revolutionary movement can... come to power."

are imprecise. The best estimates are for the years 1964 and 1966,[7,9] and even these are based on a limited survey of farmers. Still, there are some interesting facts from these surveys:

1. Over half of all pesticides used in agriculture are applied to three crops: cotton, tobacco and corn (Table III).

2. Most U. S. farmers use pesticides: 37% use herbicides, 29% use insecticides and 4% use fungicides.[9] These figures have undoubtedly increased since 1966, especially with regards to herbicides, which are used more and more as a substitute for machinery and labor. Use of organochlorides is decreasing somewhat, but use of the more toxic organophosphates is increasing.

3. A greater proportion of large farms use pesticides than small farms (Fig. 1).

4. Farmers in the Southeast and Delta states use over 40% of all insecticides. The corn belt accounts for nearly a third of the herbicides used.[7]

These facts suggest that farm use of pesticides is concentrated on a few crops, in specific regions and on large farms. However, many pesticides have been used so extensively that they must now be considered

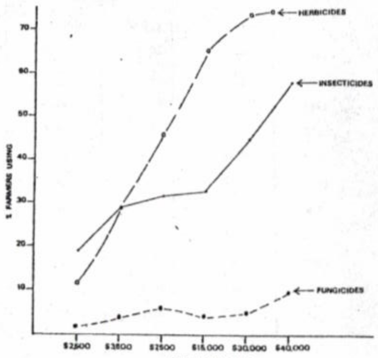


Fig. 1 Proportion of U. S. farmers using pesticides in 1966 according to size of farm operation. From USDA Agricultural Research Service.[9]

TABLE III. FARM USE OF DIFFERENT PESTICIDES ON MAJOR CROPS, 1966. Adapted from USDA, Economic Research Service.[7]

	MILLION ACRES PLANTED (1966)	PESTICIDES USED (1000 TONS)						
		FUNGICIDES	HERBICIDES	INSECTICIDES	MISC.[b]	SUBTOTAL	% TOTAL PESTICIDES	CONCENTRATION (LBS./ACRE)
COTTON	10.3	.2	3.3	32.4	14.2	50.1	26.7%	4.9
CORN	66.3	--	23.0	11.8	.5	35.3	18.8%	.5
TOBACCO	1.0	--	--	1.9	13.4	15.3	8.2%	15.3
OTHER FRUITS & NUTS	2.6	2.1	1.4	3.3	8.7	5.5	8.2%	6.0
OTHER CROPS[a]	661.5	2.3	10.1	.8	.1	13.3	7.1%	--
PEANUTS	1.5	.5	1.4	2.8	7.0	11.7	6.2%	7.8
APPLES	.7	4.2	.2	4.2	1.1	9.7	5.2%	13.9
OTHER VEGETABLES	3.7	2.1	1.7	4.1	.4	8.3	4.4%	2.2
SOYBEANS	37.4	--	5.2	1.6	.1	6.9	3.7%	.2
IRISH POTATO	1.5	1.8	1.1	1.5	.4	4.8	2.6%	3.2
WHEAT	54.5	--	4.1	.4	.1	4.6	2.5%	.1
CITRUS	1.2	2.0	.2	1.4	1.1	4.7	2.5%	3.9
ALFALFA	29.0	--	.6	1.8	.3	2.7	1.4%	.1
SORGHUM	16.4	--	2.0	.4	.1	2.5	1.3%	.2
RICE	2.0	--	1.4	.2	--	1.6	.8%	.8
SUGAR BEETS	1.2	--	.5	.1	.1	.7	.4%	.6
	890.8	15.2	56.2	68.7	47.6	187.7	100.0%	.07 .26[c]

a = includes: misc. field crops, pasture, mixed grains, summer fallow, plus those crops not listed individually.
b = includes: rodenticides, fumigants, plant hormones, miticides, repellents, defoliants, desiccants.
c = excludes "other crops"

Ecology and Economics" (3). Its message was directed both to the public and to world leaders and stated that through our ignorance of energy and nature we have created a world community that is precariously balanced. He predicted a one-hundred-fold drop in the world's population within five to twenty years, a drop closely paralleling a comparable reduction in the amount of energy available to industrial societies.

I should like to précis some of his arguments here, as the paper delivered to the Royal Swedish Academy has yet to appear in print. I apologize to him for any misinterpretations that might enter into my analysis of his ideas.

Odum views energy, whatever its source, be it coal, oil, nuclear fission or the sun and the wind, in terms of its value. By value he means real work after the energy has been extracted, processed and delivered – in a sense paid for. This is energy at its point of ultimate use. He also grades energy in terms of what it takes, energetically speaking, to make it work directly on our behalf. If it takes almost as much energy to mine, process and manufacture the components and substructures of power-producing systems and maintain the support organizations, as can be delivered for ultimate use, then the *net energy* is very slight. He argues convincingly that energy is not seen in this way by economists.

He has modeled inflation through his technique of seeing money as an energy-linked phenomenon in the "ecosystem" of nations. Seen this way, the relationships between energy and money begin to clarify. Inflation, in these terms, is directly related to the diminishing availability of net energy - as the amount of net energy readily available to a society decreases, so does the value of its money. The relationship appears to be a direct one. The quality of energy is also tied to this idea. If more energy is put into the energy-getting process, be it arctic oil, coal, or nuclear plant, than was necessary previously when fuels were more available, then less real work can be bought with the energy produced. At this point, money is worth less, independent of the machinations of high finance or government. To summarize, the value of money is directly tied to the net amount of energy available to the society that prints it.

The available energy reserves will have to be re-evaluated by both modern governments and most of their critics in light of Odum's line of argument. If net energy is the criterion upon which we are to base our planning for the future, then present estimates are much exaggerated as they are based on available reserves or gross energy. Howard Odum states, "Suppose for every 10 units of some quality of oil shale proposed as an energy source there were required 9 units of energy to mine, process, concentrate, transport and meet environmental requirements. Such a reserve would deliver 1/10th as much net energy and last 1/10th as long as was calculated."

Here we are beginning to probe the essence of the quality of energy and the dilemma beyond tomorrow. Nature has her own set of rules and what we can glean from the use of energy in ecosystems seems to apply to ourselves. From this we can see that competitive and cooperative relationships between societies have different meanings at different periods in their development.

If we are to avoid the fate that has afflicted all previous major civilizations, we will have to identify and cope with shifts in energy value. A forest, meadow, village or country will best survive if it uses its energy for the most useful purposes at any given point in time. Energy requirements can and do shift dramatically.

In nature rapid growth seems to be adaptive only during periods when new and cheap resources are available. Ruthless competition exists between plants as well as animals, when a new spacial resource becomes available. For example, when a field is cleared, colonization takes place which involves rapid shifts in species domination and abrupt rising and falling in population densities. The discovery of the fossil fuels locked in the earth's crust and subsequent use of them triggered a process in human societies in some respects analagous to those in the newly exposed field or meadow example. New energy resources became available. The scramble to exploit them was imperialistic and aggressive. Those that succeeded in obtaining these resources have in effect "changed the world."

A second phase may be approaching when readily available energies basically have been tapped. In nature, those energies remaining are used for maintenance and the gradual shift to other modes of interaction. Rapid net growth specialists like the weeds in the fields are replaced by a diversity of organisms, longer-lived, and of higher quality, with more subtle, frequently synergistic relationships which maximize their energy efficiencies. The area that was a field changes into a forest that is more diverse and stable.

Odum feels that we are going to be forced to shift from a rapid growth society to a steady state society and that we will have to begin soon or the crashes that in nature are characteristic of shifts from growth to steady states may be felt by ourselves.

There is a constructive side to his message: should we shift to a steady state system, the quality of life could, in theory, be maximized. Odum speculates that only in such a society could socialistic ideals of equitable distribution be effected.

At this point, I should like to probe the concept of energy quality and its importance in understanding the significance of the present scramble for new energy

3. H. T. Odum, 1973. *Energy, Ecology and Economics.* Paper invited by Royal Swedish Academy of Science. 26 pp.

steady-state, lower-energy societies will be those that use primarily internal energy sources and relatively high degrees of indigenous technologies in redirecting their path to safer grounds. Those with the richest internal energy sources will, I suspect, retain more of the characteristics found in high growth, cheap energy economies of today.

It is necessary for us to admit to ourselves that there will continue to be differences in relative wealth between regions in the future as there are today, but this fact should not negate the need for political consciousness to strive for social structures which maximize equality within a region. It may be that well-fed, healthy peoples with small amounts of energy available to them will redirect their lives towards stewardship and artistic and philosophic goals. Wealth as understood by materialists may be an enemy rather than an ally. I don't know this........ but I do feel that when we subtly incorporate the living world into our social consciousness, we have a better chance of surviving, and extending the human condition. An enlightened state will depend on a far greater appreciation of the underlying forces of nature.

There have been systems in nature known to have shifted from fast-growing to steady states through a gradual substitution of components from the former state to those of the latter. I suspect that, in these instances, there still existed a fair amount of reserve energy to effect the substitution. But when readily available energy is exhausted, removed, or tied up within a few species, then dramatic crashes can and do take place. Odum's point here is apt when speaking about shifts in human societies:

"Because energies and monies for research, development and thinking are abundant only during growth and not during energy levelling and decline, there is a great danger that means for developing a steady-state will not be ready when they are needed, which may be no more than 5 years away, but more probably more like 20 years."

The urgency induced by this re-evaluation of our present state is amplified by the humanitarian gestures on the part of some wealthy nations in providing food and medical aid to countries suffering from famine and disease. In Odum's opinion, this practice does not stabilize the world as we have been led to believe, but instead depletes existing reserves, ensuring that the world community will suffer en masse, instead of piecemeal. If he is right, we will find ourselves confronted with an agonizing moral crisis. The only consolation may be that, if it were known that a widespread drop in the human population were inevitable under the present modus operandi, perhaps a powerful impetus would be created to develop alternatives. Many of the techniques described in the "Journal of The New Alchemists" are designed as substitutes, utilizing what presently exists within a given region. Indigenous courses of action, to be widely effective, will require significant changes in social and political consciousness and a tremendous amount of hard work and commitment to a future that must be very different from the present.

The place of medicine within the framework of energy reductions is not well understood, but disease as the leveller of populations will again resume its primary role in the fate of humanity. Odum, seeing medicine in energetic terms, concludes that our "medical miracles" are also high energy miracles and that the energy for total medical care is a function of the total energies of a country. As the energies per person fall, energy for medicine declines and chronic disease will again become a population regulator.

Epidemics will also become more prevalent. Epidemic diseases operate under a different principle than chronic diseases. Chronic diseases test the vitality of individuals within a given population, whereas epidemics sweep through a high percentage of a population and the effects are more dramatic and widespread. Nature's systems normally use the principle of diversity to minimize epidemics. The other side of the coin is that an epidemic is a biological mechanism whereby inherently unstable monocultures are eliminated. Human societies may represent, biologically, a kind of monoculture. Certainly agriculture is characteristic of unstable systems. We have avoided crashes solely through methods that can exist only as long as there is cheap and universally available fuel. Odum's case is succinct:

"Man is presently allowed the special high yields of various monocultures including his own high density populations, his paper pine trees, and his miracle rice only so long as he has special energies to protect these artificial ways and substitute them for the disease which would restore the high diversity, ultimately the more stable flow of energy."

What is our future going to be like if we continue? Professor Odum's view of tomorrow is an unhappy one:

"The terrible possibility that is before us is that there will be the continued existence on growth with our last energies by the economic advisors that don't understand so that there are no reserves to make change with, to hold order, and to cushion a period when populations must drop a hundred-fold. Disease reduction of man and of his plant production systems could be planetary and sudden if the ratio of population to food and medical systems is pushed to the maximum at a time of falling net energy."

We are, whether we like it or not, confronted with the awesome and unprecedented task of reconstructing human societies so that they come into line with the laws of nature. Hopefully we can do it in a way that extends rather than constricts the human experience. In short, to change the world we are going to have to change ourselves. The beginnings are tangible and concrete, and there are guides including ecological concepts.

Toward a Self-Sustaining Agriculture

Take not too much of a land,
wear not out all the fatness,
but leave in it some heart.

– Pliny the Elder
A. D. 23-79

Farming isn't a way of life,
it's a way to make a living.

– Earl Butz
U. S. Secretary of Agriculture

The fact that a culture can produce more food on less land with less human toil has been cited by people of many persuasions as a prime example of human "progress." Until recently there has been little reason to challenge this belief. As long as an agriculture produced food for its people and a surplus for foreign trade, the farm technologies used and the economic incentives encouraging them were justified.

The fallacy here lies in the assumption that the *only* purpose of agriculture is to produce food. Over the years many kinds of propaganda have locked us into this dangerous illusion, and we tend to forget that agriculture is dynamic and that its historic role has been to maintain productive land in order to sustain its people. In addition, a thriving rural culture has been vital in providing food and fibre and in absorbing dispossessed people during wars and economic depressions. [1] In a healthy society, agriculture provides not only food, but also a reliable buffer during social crises and a legacy of land stewardship for posterity.

Like most rapid revolutions, the green revolution has created more long-term problems than short-term "solutions." At first glance, the new farm technology is praised because it has allowed millions to leave their lands for a fantasized urban paradise free from rural toil. But, in the haste to free the majority of people from the need to work the land, an enormous dilemma has been created. The tools of liberation..... chemicals, machinery, monocultures, hybrid crop strains, etc., while they have alleviated scarcity and one kind of work, at the same time have precipitated mounting economic and ecological problems which not only compound themselves, but also threaten the sustaining potential of our farmlands. Since World War II, we have so altered our rural environment and have become so totally dependent upon a single chemical strategy for food production that we face a future in which a major human concern must be the increasing hazards of supplying the fuels and chemicals needed to keep the food coming. We brag of being a nation where food is relatively cheap and agriculture efficient, yet ignore the fact that most measures of food prices and farm efficiency fail to take into account the endangerment to such valuable resources as soil fertility, water, wildlife, public health and a viable rural economy. When we stop to consider the full impact of the agricultural tools that have replaced the people who have crowded into the cities, it is clear that "modern" agriculture is causing more problems than it is solving.[a]

There are other problems associated with the green revolution beyond those of environmental hazards and the destruction of a healthy rural base. Today's farms require massive inputs of fossil fuel energy to maintain them in a stable state. In fact, during the last few decades we have simply been exchanging finite reserves of fossil fuels for our supplies of food and fibre. Obviously, this trade-off cannot continue indefinitely; if agriculture is energy-intensive, then fuel shortages must inevitably lead to food shortages. In the very near future, we

a. The amount of U. S. farmland under cultivation has actually decreased over the last generation. Unfortunately the urbanization of prime farmlands is beyond control. Opening up marginal lands for farming requires high-energy technologies and increases the threat of pollution and exploitation of finite resources. It is a vicious problem with no obvious solution under present priorities of uncontrolled growth and development.

will have no choice but to adopt agricultural techniques that utilize renewable energy supplies. These include: the recycling of organic wastes to supplement synthetic fertilizers; the use of renewable forms of energy (solar, wind and organic fuels), to help supply rural power needs; the application of ecologically diverse cropping patterns and integrated pest control programs to reduce the use of pesticides. Without a broad approach to these alternatives, modern agriculture could well become self defeating rather than self sustaining.

The full consequences of the green revolution present a number of unresolved questions concerning the relationship between modern agriculture and the quality of life. In the past, many of these questions have been considered rhetorical or academic. Today they suggest forcefully that we have not been adjusting our priorities to the accelerated pace of current events. For example:

1. What is the total impact of modern agriculture on our indispensable natural resources?

2. What are the long-term effects of pesticides and synthetic fertilizers on public health and on the continuing ability of farmlands to produce quality food?

3. Is the displacement of rural culture by high-energy technology an inevitable or even desirable consequence of social "progress"? If not, how can economic policy and public sentiment be changed to encourage the success of independent farmers who are best able to safeguard the rural environment for future generations?

4. What are the consequences of an agricultural system totally dependent upon non-renewable supplies of fossil fuel energy? Is not such an agriculture itself non-renewable? Do further increases in food production justify additional uses of fossil fuel resources?

5. Will increasing costs of fossil fuels mean total monopoly of agriculture by corporations, industry and the petroleum technology? If so, what effects will this have on price, availability and quality of food?

6. Why does agricultural research continue to focus attention on developing farming methods that are geared to machines and fossil fuels rather than people and renewable energy inputs? Why do ecologically sophisticated techniques of agriculture continue to be considered "inefficient" and "backward" by the U. S. Department of Agriculture and much of the scientific establishment?

7. To what degree can the polluting, high-energy techniques of agriculture be replaced by the renewable and self-sustaining energy of natural resources and biological processes?

MODERN AGRICULTURE: A WASTELAND TECHNOLOGY

The new (farm) technology is
an economic success because
it is an ecological failure.
— Barry Commoner

By its very nature, agriculture makes a heavy impact on the environment. Ever since neolithic tribes began to cultivate endemic wild plants, agriculture has involved a tradition of people manipulating their surroundings in order to grow plants and to husband animals for food. The results have often been unfavorable. Throughout history, people have accelerated natural erosion by rapid deforestation and poor soil management. Frequently the cultivation of plants for export has also placed a strain on local economies.[2,3] In the United States, land destruction has been a matter of record since 17th century tobacco and cotton farming in the south. Wind erosion and the midwest dust bowls of the early 1900's are now infamous history. Current data from the national land-use inventory show that 64% of the U. S. croplands are in need of soil conservation.[4]

Today, however, the traditional hazards of agriculture are overshadowed by an arsenal of sophisticated technologies which cast the environmental impact of agriculture in new dimensions.

PESTICIDES: OVERKILL AND DIMINISHING RETURNS Pesticides are poisons which kill pests; insects (insecticides), weeds (herbicides) and plant diseases (fungicides). Prior to 1940, pesticides were made from inorganic materials (mostly heavy metals, arsenic and sulfur) or plants. Just before World War II, it was discovered that DDT, a synthetic organic compound first made in 1874, had remarkable insecticide properties. Wartime conditions increased the demand for DDT, and, after the war, U. S. production soared from 9½ million pounds in 1944 to 179 million pounds in 1963.[5] Other requirements led to the development of more toxic insecticides, which included variants of DDT and certain nerve poisons such as the organophosphates (developed as by-products of nerve gas research during World War II) and carbamates.

The popularity of herbicides was inaugurated by a revolutionary chemical developed during World War II. The compound, 2, 4-D, was especially appealing because it acted like a plant hormone, selectively poisoning broad-leaf plants but not grasses. This was

energy, will be able to bail us out if we don't restructure the human landscape of this country.

Nuclear energy is considered by many high technology advocates to be their trump card, but this is a myth the perpetuation of which is in part responsible for continuing on our ill-fated course. Professor Odum, in discussing the energetics of nuclear energy, does not feel the need to go into the dangers inherent within the use of the atom in order to make us rethink what we are presently doing in promoting a large nuclear industry. On the other hand, I think the safety factors, nuclear waste storage and the slow but steady build-up of radioactive materials in the environment are justification enough not to develop nuclear energy as the panacea to all our energy problems. Odum's argument rests on the fact that the net energy from nuclear power plants is low, being presently subsidized by coal and gas economies.

In his talk to the Royal Swedish Academy, he states,"High costs of mining, processing fuels, developing costly plants, storing wastes, operating complex safety systems and operating government agencies make nuclear energy one of the marginal sources which add some energy now, while they are subsidized by a rich economy. A self-contained, isolated nuclear energy does not now exist. Since the present nuclear energy is marginal while it uses the cream of rich fuels accumulated during times of rich fossil fuel excess, and because the present rich reserves of nuclear fuel will last no longer than fossil fuels, there may not be major long-range effect of present nuclear technology on economic survival. High energy cost of nuclear construction may be a factor accelerating the exhaustion of the richer fuels."

The use of breeder reactors is the next link in the efficiency chain. They use less fuel in the production of electricity. However, their net yielding ability is not yet known, in part because of the huge research and development costs involved. Further, contemporary nuclear plants may consume the fuels needed by the breeders before breeder technology comes of age, so we may never know whether or not they could be net yielders, independent of fossil fuel subsidies.

Nuclear enthusiasts are often quick to point out that the ultimate solution to energy in society lies in creating fusion plants; the fusion phenomenon being akin to fabricating small "suns" here on earth. But workable pilot plants have yet to be developed, and there is no concrete knowledge either as to potential net energy or as to how large an energy subsidy will be required. Societies may not be able to afford to shift to the fusion process from their oil and coal bases, even if the concept of fusion should, one day, prove workable.

If the above concepts have a basis in fact, as I believe they do, it is possible to look with fresher eyes into the dynamic of our present society. The picture that emerges is one of instability and unhappy changes unless we begin to create anew human communities within the limits placed upon us by the living world upon which we depend.

Countries and regions within countries operating upon their own energy resources require less money to function and are in a fortunate position when they export goods and services. Perhaps a corollary of this point is that regional development should be tied more closely to indigenous energies when the future in the long term is seen as being more important than short term wealth and instability. Certainly such an approach would tend to enhance diversity and stability within a region. It might be argued, and quite rightly, that disparities between regions would arise and that the inhabitants of less favorably endowed areas would be poorer. This is partly what I mean by the term, "the limits of nature." Present disparities between regions are sometimes equalized only because of an abundance of cheap energies. This cannot be sustained for long. I have seen communities within a few miles of each other in Haiti, where non-human energy is very expensive and scarce, that are totally different. The root of the differences lies in the local ecosystems themselves. It is when the less fortunate are inextricably dependent on the more fortunate for survival that oppression and injustice reaches its peak.

I would like to suggest that there might be compensations, even though disparities will be generally seen in a negative light. If it were somehow possible to adjust the size of a given community or population to the ability of the surrounding landscape to sustain it, then viable societies might evolve. In these cases, the social goals of equality would have to be worked out within the framework of a region's productive capacity. It may be that sophisticated political theory will one day tell us that an optimal social/political course within a rich and fertile river valley will be different than one for residents of high mountain valleys with inhospitable climates, even given the same goal of maximizing the human experience. In designing adaptive societies, ecological realities need to be placed within the political sphere.

Countries that have high amounts of energy to sell are, in Odum's view, in a strange predicament. If they sell oil (a rich energy source) and don't use it for useful work at home, they too become subordinate nations requiring technical goods and services. Many Arab nations are becoming increasingly aware of this and are shifting more of their energy to manufacturing within their own boundaries. Should they do this on a wide scale they could topple energy-poor manufacturing nations like Japan. Japan's future could provide a barometer of the eventual fate of modern industrial nations.

Those countries or regions that will have the best chance of shifting from their present course closer to